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ABSTRACT

Even in today's mathematics classroom, where teachers often focus primarily on mastery of underlying concepts, students struggle to commit the multiplication table to memory. Facility in multiplication involves both an understanding of the concepts and memorization of the facts. Successful memorization of the one hundred basic multiplication facts improves a child's ability to solve more involved problems. While experts agree that students must quickly retrieve multiplication products from memory, existing research draws varied conclusions concerning the effectiveness of different approaches to helping students memorize multiplication facts. In this study, the researcher used mnemonic devices to review basic multiplication facts with a group of fourth grade students who had previous instruction in multiplication. The researcher conducted this study with twenty-three students from a public school in East Tennessee. Prior to the study, the researcher administered an informal timed test of single-digit multiplication problems. Using results obtained in the screening, the researcher formed a control group and an experimental group of assumed equal abilities. During twelve days in a three-week period, the researcher removed each group from the classroom for a teacher-directed practice session of multiplication facts. The control group used repetition to review basic facts while the researcher presented the experimental group with a mnemonic device to help subjects remember each fact. Practice sessions lasted for ten minutes. After the study, all subjects took a timed post- test of single-digit multiplication facts. An independent sample t-test analyzed the raw scores from the post-test. Results indicated that practicing multiplication facts with mnemonic devices did not produce significant differences in the mean scores of fourth grade students on a timed multiplication test. The researcher retained the null hypothesis. (Contains 41 references.) (Author/YDS)

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USING MNEMONIC STRATEGIES
IN FOURTH GRADE MULTIPLICATION

An Action Research Project

Presented to

the Department of Teacher Education

of Johnson Bible College

In Partial Fulfillment

of the Requirement for the Degree

Master of Arts in

Holistic Education

by

Anita Kay Zutaut

July 2002

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APPROVAL PAGE

This action research project by Anita Kay Zutaut is accepted in its present form by the Department of Teacher Education at Johnson Bible College in partial fulfillment for the requirements for the degree Master of Arts in Holistic Education.

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Chapter 1

INTRODUCTION

Students of ancient Mesopotamia copied multiplication tables in scribal schools (Nemet-Nejat, p. 241). For generations, the educated elite considered mastery of multiplication an essential component of mathematical learning. Today, millenniums from Old Babylonia, elementary school children still struggle to commit multiplication facts to memory. Memorization of multiplication tables plays a prominent, often frustrating, role in the educational process of many American children.

Significance of the Problem

Multiplication concepts comprise a significant portion of elementary school mathematics. Facility in multiplication skills involves both an understanding of concepts and memorization of the facts. In supporting the use of memorization in mathematics, Sharma notes the importance of "the use of memorization in teaching and learning," when coupled with conceptual understanding (Sharma, p. 3). The National Council of Teachers of Mathematics calls knowing the basic multiplication pairs "essential" (National Council of Teachers of Mathematics, p. 32). At the same time, the organization emphasizes that students should "understand meanings of operations." According to the council's 2000 standards, students in grades three through five should "develop fluency with basic number combinations for multiplication" and should "develop fluency in . . . multiplying whole numbers" (National Council of Teachers of Mathematics, p. 148).

Multiplication skills lay the foundation for many higher mathematical tasks. Heege emphasizes the importance of committing multiplication facts to long-term memory. According to Heege, "it costs a student who doesn't know or knows insufficiently the basic multiplication facts so much effort to do . . . column arithmetic that he or she will easily give up" (Heege, p. 378-379). Students who fail to master basic multiplication facts may hinder their abilities to solve more complex problems (Huang and Chao, p. 662).

Statement of the Problem

Mastery of the basic multiplication facts is crucial, but for many students, mastery is neither automatic nor easy. Campbell and Graham found that even after four years of multiplication practice, fifth graders still made errors on at least 12.5% of the trial problems (Campbell and Graham, p. 348). Fourth grade students often struggle to quickly retrieve correct products of single-digit multiplication facts. Campbell and Graham suggest that "providing rules or mnemonics during learning that constrain the set of plausible candidates for specific problems" may facilitate acquisition of multiplication skills (Campbell and Graham, p. 361). This study investigated the influence of using mnemonic devices to aid children's memorization and recall of single-digit multiplication facts.

Definition of Terms

Mnemonic- "a device, procedure, or operation that is used to improve memory" (Mastropieri and Scruggs, p. 271)

Limitations

The researcher served as the experimenter, which introduced potential bias into the results.

This study involved a small number of students in one classroom, not a randomly selected sample from the entire population.

Subjects were assigned to control and experimental groups based on an informal screening conducted before the beginning of the study. Full randomization was not achieved.

Possible prior exposures of control group students to mnemonic devices for learning multiplication could have influenced post-test scores.

The post-test used to determine raw scores was a teacher-made test, not a nationally standardized assessment.

Assumptions

The researcher made the informed assumption that students possessed basic understanding of multiplication concepts and that students had been previously exposed to single-digit multiplication facts.

The researcher also assumed that the control and experimental groups began with the same level of competence in recall of single-digit multiplication facts.

Null Hypothesis

Students who receive instruction with mnemonic devices will show no significant difference in overall mean scores on a multiplication test compared to the mean scores of students who receive no instruction with mnemonic devices. The researcher will test this hypothesis at the .05 level of significance.

CHAPTER 2

REVIEW OF RELATED LITERATURE

Development of Multiplication Skills

Gaining an understanding of the concept of multiplication is the first step toward mastering multiplication skills. Teachers often use concrete manipulatives and visual models to illustrate the meaning of multiplication. After students grasp the meaning of multiplication, they begin to solve simple multiplication problems. In the beginning, solution strategies may involve using manipulatives and drawing pictures. As students progress to abstract levels, they use various mental strategies to obtain products. Young multipliers often employ reconstructive methods such as counting and repeated addition (Koshmider and Ashcraft, p. 53). Mastery of multiplication facts occurs as students increasingly rely on memory retrieval to solve simple multiplication problems.

While problem-solvers of all ages use multiple problem-solving strategies, the prevalence of these strategies changes with multiplying experience. Research indicates that as multipliers mature, they transition from using counting-based strategies to using retrieval strategies (Koshmider and Ashcraft, p. 55). A study of multiplication in French second -graders indicated that throughout the year, retrieval "came to be executed more and more accurately over sessions" (Lemaire and Siegler, p. 89). Koshmider and Ashcraft concluded that third graders use nonretrieval strategies, such as reconstructive processing, for problems that are weakly stored in memory (Koshmider and Ashcraft, p. 61).

Difficult problems are most frequently solved by non-retrieval strategies, while easier problems are most often solved by retrieval (Lemaire and Siegler, p. 84).

Research findings argue "against counting-based solutions as the most dominant process for children's multiplication" (Koshmider and Ashcraft, p. 70). Increased use of retrieval leads to increased speed and accuracy (Lemaire and Siegler, p. 84). Lemaire et. al. concluded that "by third grade, children's knowledge of some addition and multiplication facts has reached sufficient strength to be routinely retrieved" (Lemaire et. al., p. 255). In fact, retrieval seems to be the most dominant strategy, even in third grade students (Koshmider and Ashcraft, p. 70).

Lemaire and Siegler used the adaptive strategy choice model (ASCM) to provide an explanation for the phenomenon of changing strategies, and specifically for the increased use of retrieval (Lemaire and Siegler, p. 84). According to the ASCM model, when the brain is presented with a problem stimulus, it selects a strategy. If the chosen strategy is not retrieval, the brain chooses a possible answer from numbers associated with that problem. The stronger a number's association with that problem, the more likely it is to be chosen as the product. Because "backup strategies produce the correct answer more often than any single erroneous answer," the correct answer becomes increasingly associated with the problem set" (Lemaire and Siegler, p. 85). In testing French second graders, Lemaire and Siegler found that "a child's percent correct on backup strategy trials in Session 1 was a significant predictor of the child's percent correct on retrieval trials in Session 2" (Lemaire and Siegler, p. 93). The strength of the association increases as the solver gains experience with the problem. As the association grows, the probability of using retrieval as the solving strategy increases. By the last testing session, the children used retrieval on over 90% of the trials (Lemaire and Siegler, p. 94).

Koshmider and Ashcraft conducted an experiment designed to test the age of onset of automatic retrieval and changes in retrieval usage (Koshmider and Ashcraft, p. 73, 77). Researchers presented randomly selected multiplication facts to subjects for varying amounts of time. Each problem was presented twice, once preceded by no number and once preceded by a number relevant or irrelevant to the problem. Data was collected from third graders, fifth graders, seventh graders, and undergraduates. A mixed model analysis of variance showed a standard decrease in reaction time across age (Koshmider and Ashcraft, p. 80). This indicates an increase in retrieval skills as students grow older.

<u>Automaticity in Multiplication Facts</u>

Jensen and Whang characterize automatic processing of multiplication facts as those not requiring full attention and those which are basically effortless (Jensen and Whang, p. 2). Automatic processing allows a problem-solver to "deal with relatively large amounts of information and perform operations on it simultaneously." When arithmetic facts are automatically retrieved, they interfere less with working memory. Huang and Chao note that "lack of fluency in basic skills interferes with solving more complex problems" (Huang and Chao, p. 662).

Koshmider and Ashcraft hypothesized that a test of reaction times on a true/false multiplication test would provide evidence for retrieval, even in third grade students (Koshmider and Ashcraft, p. 57-59). They used two hundred trials of the one hundred basic multiplication facts in random order. One time the fact appeared with the correct answer and another time the fact appeared with an incorrect answer. Trials were presented on a microcomputer screen. Results indicated that "fact retrieval dominates children's performance on simple multiplication facts as early as the third grade" (Koshmider and Ashcraft, p. 73).

Cultural differences may exist in the speed of processing of multiplication facts. Jensen and Whang tested the reaction times of Anglo-American and Chinese-American fourth- through sixth-graders in Northern California who had been screened to ensure that they already knew basic facts (Jensen and Whang, p. 3). Subjects viewed addition, subtraction, and multiplication problems on a computer screen and pressed a button to indicate whether the shown answer was correct or incorrect (Jensen and Whang, p. 4). The researchers found that Chinese-American students had statistically significant reaction times on multiplication facts (they averaged 143 ms faster), compared to Anglo-American students. (Jensen and Whang, p. 6-7). After ruling out intelligence differences and differences in test motivation between the Chinese-Americans and Anglo-Americans, the researchers concluded that the Chinese-American students "showed quite markedly and very significantly faster processing speed" (Jensen and Whang, p. 11). Researchers, however, also acknowledged that the faster reaction times of Chinese-American students could stem from more extensive practice of the mathematics facts than their Anglo-American counterparts had experienced (Jensen and Whang, p. 11).

Methods of Teaching Multiplication Facts

Some educators advocate using visual symbols to help students gain facility with multiplication facts. Armstrong believes in the effectiveness of using patterns and relationships to teach multiplication. In teaching single-digit multiplication, Armstrong suggests having each student create a chart of multiplication facts by "cutting arrays from paper grids to represent multiplying 1 X 1 through 9 X 9" (Armstrong, p. 447). She then requires that students fill in numbers on a traditional multiplication table. Throughout the lesson, the educator encourages students to discover patterns in the multiplication facts. Outcomes in one classroom indicated that this teaching method helped students connect their previously limited knowledge of multiplication facts (Armstrong, p. 451).

Computer assisted training provides another method of instruction. Elementary students increasingly use computer programs to master multiplication facts. Wittman and his colleagues tested the effectiveness of the Math Builder computer program when used by fourth grade students to practice multiplication facts (Wittman, Marcinkiewicz, and Hamodey-Douglas, p. 2). The research indicated that all of the subjects automatized the facts, and that the resulting automatization lowered math anxiety in the students.

Fasko examined the effectiveness of peer tutoring in improving fourth and fifth grade students' recall of multiplication facts (Fasko, p. 3). After training peer tutors, the researcher assigned each tutor a tutee. Peer partners worked together for approximately one hour a week. Fasko collected data from worksheets and multiplication fact probes.

Results indicated improvement in fact fluency for seventy-five percent of the students and improved performance on worksheets during the sessions for all the subjects.

Several studies have investigated the effectiveness of various methods used to teach multiplication to students with learning disabilities. When researchers taught a fourth grade student with learning disabilities to transfer a multiplication problem to an oral and/or written count-by problem, the rate per minute of problems correct increased substantially (McIntyre et. al., p. 82). In count-by problems, students extend the usual counting patterns of two's and five's to count-by numbers such as four and six, which teachers do not traditionally introduce.

Huang and Chao provided individual help with multiplication facts for two adolescent students with learning disabilities (Huang and Chao, p. 662). A teacher used manipulatives and drawings to explain basic multiplication concepts. Following the instruction, the students practiced multiplication facts with the teacher for ten minutes and independently for fifteen minutes. Post-test results showed a forty to fifty percent improvement during the intervention, with results retained two weeks after the study.

Teaching learning disabled students with the pegword memory strategy for learning multiplication facts has received recent attention. Wood et. al conducted a study in which three fifth-grade students with learning disabilities received small-group math instruction for thirty to forty-five minutes per day (Wood et. al., p. 325). Students were taught the following strategies for learning multiplication facts: Zero multiplied by anything is zero. One times a number is always the number (Wood and Frank, p. 78-79). Students learn the two strategy through visual images on flashcards: "2 x 2 --a skateboard with two sets of wheels, 3 x 2 -- a six pack of pop" (Wood and Frank, p. 80). Counting by five's is used to learn the multiplication facts containing fives. In the nine strategy, multipliers learn to subtract one from the number that is not nine. They put the answer to the subtraction problem in the tens place. They then find the answer to the subtraction problem on a chart, where it is linked to another number in such a way that the sum of the two numbers is nine. Students place this number in the ones place.

After students know the zeros, ones, twos, fives, and nines, only fifteen facts remain. Teachers familiarize students with a rhyming pegword for each of the numbers associated with a missing fact. For example, students associate the number three with a "tree" and the number nine with a "line" (Wood and Frank, p. 80). To learn three times three, students create a visual association of two trees on a line. Wood and her colleagues documented the effectiveness of the teaching strategies employed. Both the rules and pegword strategies yielded improvement in participants' multiplication fact recall (Wood et. al, p. 333). In addition, "participants appeared to be more enthused about math instruction throughout the implementation of the instructional package, compared to baseline" (Wood et. al, p. 334).

<u>Processing Strategies</u>

Multipliers of all ages employ a variety of strategies to obtain products. Heege noted that children make use of rules such as the commutative property to obtain products (Heege, p. 383). Young students take advantage of the ease of multiplying by ten and also "calculate certain products by doubling." Some children halve familiar multiplication problems to obtain other answers. This occurs mainly with a multiplicand of 5. Students may "increase a familiar product by adding the multiplicand once" or "decrease a familiar product by subtracting the multiplicand once" (Heege, p. 384).

In a study of undergraduates, LeFevre et. al. found that subjects used five strategies to solve simple multiplication problems (LeFevre et. al., 1996, p. 284). They coded strategies as retrieval, derived-fact, repeated-addition, number series, or nines rules (p. 289).

Repeated addition occurs when a subject adds a factor the indicated number of times. Multipliers either add the bigger multiplicand the number of times indicated by the smaller, or the smaller multiplicand the number of times indicated by the bigger. A study of French second-graders examined changes in repeated addition strategies over the course of the year. Students were individually given multiplication problems to solve in ways of their own choosing. Researchers videotaped the subjects and analyzed their problem solving strategies. They found that subjects increasingly executed repeated addition by adding the bigger multiplicand the number of times indicated by the smaller (Lemaire and Siegler, p. 89). Percentage of students using this method of repeated addition increased from 46% on the initial trial to 86% on the final trial.

Subjects who used other arithmetic facts to solve the multiplication problem used derived-fact procedures. Participants used a number series strategy when they counted by fives, twos, threes, etc. to solve the problem. Nines rules involved using algorithms specific to that set of facts, such as subtracting one from the smallest operand and making sure the answer digits added to nine.

Researchers considered retrieval strategies those about which the subject claimed that he or she "just knew" or solved from memory (LeFevre et. al., 1996, p. 289). LeFevre and her colleagues found that retrieval was the most frequently used and the fastest strategy (1996, 292-293). In an experiment involving third-grade students, Koshmider and Ashcraft found that in solving multiplication problems, "even third graders rely heavily on memory retrieval rather than on reconstructive procedures such as counting" (Koshmider and Ashcraft, p. 53).

Errors in Multiplication Processing

LeFevre et. al. categorize multiplication errors as operand-related, operand-unrelated, and operation errors (LeFevre et. al., 1996, p. 285). Operand-related errors occur when the incorrect answer shares a factor with one of the operands (e.g. 4 X 7 = 21). Operand-related errors constituted 76% and 73% of the mistakes in the study conducted by LeFevre et. al (1996, p. 290). Operand-unrelated errors are those in which the wrong answer is the correct answer for another multiplication fact (e.g. 8 X 3 = 28). Lemaire and Siegler categorize these as table errors (Lemaire and Siegler, p. 89). Operation errors occur when the subject performs the wrong operation, usually adding instead of multiplying. Lemaire and Siegler added the categories of operand repetition errors and non-table errors (Lemaire and Siegler, p. 89). Operand repetition errors occur when one of the multiplicands is given as the answer. Non table errors are "incorrect answers that do not fall into any of the other categories."

<u>Generation Effect in Multiplication</u>

The generation effect describes a phenomenon in which items that are generated by a subject are more likely to be remembered than items that are simply read by a subject. McNamara and Healy define the generation effect as "a robust retention advantage found for material that is self-generated compared to material that is simply copied or read" (McNamara and Healy, p. 652). According to these researchers, in order for the generation effect to occur, the generation of an answer must cause subjects to use cognitive operations to connect the "target item to information stored in memory" (McNamara and Healy, 1995, p. 415).

Gardiner and Rowley demonstrated the existence of the generation effect in multiplication (Gardiner and Rowley, p. 443-444). Undergraduate students studied a list of multiplication problems. Half of the answers were given and read by the students. The students generated the other half of the answers. After this, subjects took either a recognition or recall test for the products. In both instances, subjects recalled significantly more answers from the generate condition. Pesta, Sanders, and Murphy also studied the generation effect in undergraduates' multiplication skills and found that "the generation effect is larger when a participant computes an answer than when he or she retrieves an answer from memory" (Pesta, Sanders, and Murphy, p. 112).

McNamara explored practical applications of the generation effect in elementary school children. Researchers gave second grade students simple and brief multiplication instruction (McNamara, p. 309). After the initial training, students were given a pretest and then four sections of either read or generate training. In generate training, students solved multiplication problems on their own. In read training, students entered the multiplication problems into a calculator and read the products. Post-test results support a limited preference for generation strategies in instruction. The effectiveness of a strategy depended upon the subject's multiplication ability before the training. For example, "generate training was found to be completely ineffective for the children who accurately solved more than 70% of the pretest problems but highly effective for children who solved correctly less than 70% of the problems" (McNamara, p. 314). Read training was "moderately effective" for all children; however it was "clearly less effective than generate in children with less prior knowledge of multiplication" (McNamara, p. 315). McNamara concluded that generation of answers is most effective in initial stages of learning, but that read training is adequate to increase accuracy after subjects gain knowledge of multiplication (McNamara, p. 316).

Interference Effect in Multiplication

Much evidence exists for an interference effect, sometimes called the confusion effect, in multiplication. Numbers related to the product often slow reaction times in verification tests, or are given as incorrect answers. Both sums of numbers and numbers close to the product may cause interference. Lemaire and his colleagues conclude that "the associations between a number pair and its sum or product are of sufficient strength during the elementary school years to produce interference effects in a variety of situations" (Lemaire et. al., p. 251).

While sum interference is more prominent in adults, number-line proximity may be the most confusing form of interference in children (Lemaire et. al, p. 227). Lemaire et. al note that "sum activation only plays a minimal role in producing confusion effects prior to sixth grade" (Lemaire et. a., p. 234). Nevertheless, sum activation does produce some confusion effects in students from second to fifth grade. LeMaire et. al. presented students with two numbers unconnected by operation and followed the original stimulus with a probe number. The probe number was either an unrelated number or the sum of the stimulus digits. According to the researchers, "at all grade levels, the sum probes were associated with higher error rates" (Lemaire et. al., p. 239).

Lemaire and his colleagues attributed the emergence of confusion effects in children to an associative model of mathematical memory (Lemaire et. al., p. 243). They noted that as the year progressed, advanced second-graders and third-graders required more time to solve addition problems. Because the time increase happened concurrently with the children's learning of multiplication, and because of changes in errors, Lemaire et. al. propose that the increased solution times resulted from interference effects as the brain activated both sums and products. According to the researchers, "the percentage of cross-operation errors was highest for third- and fourth-graders and reached its peak in the middle of fourth grade." Lemaire et. al. presented third, fourth, and fifth graders with sets of true and false (confusion and non-confusion) addition and multiplication problems and asked the students to classify the problems (Lemaire et. al., p. 244). Students were tested three times over the course of a school year. The researchers found that an associative confusion did exist among fourth-graders. Results indicate that "as children master multiplication facts, confusion effects due to product activation become more prevalent" (Lemaire et. al., p. 249).

Problem-Size Effect in Multiplication

Koshmider and Ashcraft define the problem size effect as "in increase in RT [reaction time] as the size of the problem increases" (Koshmider and Ashcraft, p. 54). In their study of third graders to college students, they found that "small problems were verified 317 ms faster than large problems" (Koshmider and Ashcraft, p. 60-62). In addition, third graders' error rate on small problems was 4.3%, but on large problems it was 19.0%. However, problem-size effect played an increasingly smaller role as students got older.

Several theories exist concerning the origin of the problem-size effect. Reconstructive theories say that larger problems require either more steps or more difficult steps to solve, and therefore take more time (Zbrodoff, p. 691-692). Strength theories propose that the problem-size effect exists because people have more experience solving small problems than large problems. Adherents to interference theories believe that the problem-size effect stems from the interference an answer gathers from another answer. Zbrodoff used an alphabet-arithmetic task with undergraduates to study contributors to the problem-size effect in addition. She proposes that a combination of strength and interference effects best explain the problem-size effect, at least with respect to addition (Zbrodoff, p. 698). Manly and Spoehr, however, concluded that the "relative effect of different contributions to the problem-size effect" depended in part on the nature of the problem itself (Manly and Spoehr, p. 1095).

<u>Storage of Multiplication Facts in Long-Term Memory</u>

Most researchers adhere to the associative structure model of mathematical memory. Proponents of the associative structure model suggest that the long-term memory stores simple multiplication facts in a network (Koshmider and Ashcraft, p. 55). By the process of spreading activation, the presence of a number or numbers spreads along associated links so that related number nodes are activated (Lemaire, p. 225). As Pesta, Sanders, and Murphy note, "each answer in the network connects to every other answer, but associative strength determines the semantic distance between two nodes" (Pesta, Sanders, and Murphy, p. 111). Factors that influence the formation of the associative network include related knowledge, the difficulty of using non-retrieval strategies, and frequency of problem exposure (Baroody, p. 94). In this model, the strength of the association between a problem and its answer best predicts reaction times.

LeFevre, Bisanz, and Mrkonjic provided evidence for the associate structure model in their study of undergraduates. These researchers presented simple addition problems followed by a probe number which was either one of the two addends, the sum of the addends, or an unrelated number (LeFevre, Bisanz, and Mrkonjic, p. 45). Reaction times were significantly slower for problems in which the probe number was the sum of the digits. This supports the associative model's framework of related nodes being activated in the presence of number stimuli.

Further support for an associative network comes from Milikowski and Elshout's investigation of differences in semantic integration of tabled and non-tabled numbers. Undergraduates were given numbers one to one hundred in random orders and were instructed to write down numbers associated with the number (Milikowski and Elshout, 1994, p. 31). Subjects had thirty seconds to complete each response. Subjects responded with significantly more associations to numbers found in the multiplication table than to non-tabled numbers. According to the researchers, this seems to indicate that "tabled numbers have more connections in semantic memory than do non-tabled ones" (Milikowski and Elshout, 1994, p. 32).

In a follow-up experiment, Milikowski and Elshout instructed undergraduates to respond with either the first number that came to mind or with a number that was related to the number. Researchers found that the tabled numbers had a significantly shorter reaction time than did the non-tabled numbers (Milikowski and Elshout, 1994, p. 34). In a separate experiment, Milikowski and Elshout found that undergraduates were more likely to recall and recognize tabled numbers than non-tabled numbers that were not single-digit numbers, teen numbers, or doubled numbers (Milikowski and Elshout, 1995, p. 537).

Mnemonics

Carney, Levin, and Levin define a "mnemonic" as a "memory-improving" strategy (Carney, Levin, and Levin, p. 25). Research indicates that mnemonic strategies benefit learners with a broad spectrum of ages and abilities (Carney, Levin, and Levin, p. 26). Applicable to virtually any subject, mnemonic strategies help the learner recode information that needs to be memorized, relate the information to other knowledge, and retrieve the information from memory. According to Carney, Levin, and Levin, "mnemonic strategies work by adding meaningful connections to seemingly unconnected or arbitrarily connected pieces of information" (Carney, Levin, and Levin, p. 25).

Greene compared the effectiveness of mnemonic and traditional instruction in teaching multiplication facts to elementary and middle school students with learning disabilities (Greene, p. 141). All students received both the mnemonic and the traditional treatment. The traditional treatment consisted of flashcards with a multiplication fact and answer on one side of the card and a multiplication fact without the answer on the other side of the card. Mnemonic treatment consisted of "a multiplication algorithm and answer on one side with a cartoon illustration drawn below the numbers in the multiplication fact" (Greene, p. 142). In addition, the experimenter verbally introduced pegwords and pegword phrases corresponding to the cartoons to the subjects. Statistical analysis of posttest results indicate that "mnemonic training contributes more to the retention of math facts than do traditional methods of instruction" (Greene, p. 146).

Some controversy exists regarding the use of mnemonic strategies in teaching mathematical facts. Simpson believes that mnemonic strategies promote rote memory of mathematical facts, but hinder understanding of mathematical concepts (Simpson, p. 3). He proposes that "rote language mnemonic devices are certainly not the most effective instruments for implanting fluent *memory* of number facts" (Simpson, p. 4). In Simpson's view, using words, a linguistic concept, to teach a numerical concept may cause such ineffectiveness. He says that "rote language mnemonic devices" are "inefficient, stressful, and unrelated to the process of mathematical exploration" (Simpson, p. 5).

Wang and his colleagues compared the acquisition and retention of French vocabulary words using mnemonic devices and traditional methods. Contrary to the researchers' initial expectations, the study indicated that subjects using "mnemonic devices forgot at a faster rate than subjects rote rehearsing the same information" (Wang et. al, p. 3). Wang admits that these results could have occurred because of interference effects or use of unfamiliar learning strategies. He and his colleagues conclude that while it is "clear that memory aids enhance learning performance and immediate recall, there exists no direct evidence indicating that mnemonic devices confer a long-term advantage when forgetting is evaluated" (Wang et. al, p. 2).

Conclusion

A large body of research regarding memorization of multiplication facts exists. Problem-solvers use varying strategies to obtain products of multiplication problems. As experience with multiplication increases, strategies progress from counting-based procedures to retrieval. A number of researchers have investigated the use of specific strategies in helping students retrieve the products of multiplication problems. Mixed conclusions about the effectiveness of combining mnemonic strategies and mathematical memorization warrant further research regarding this topic's practical value in today's classroom.

CHAPTER 3

METHODS AND PROCEDURES

Subjects

The subjects of this study were twenty-three fourth grade students from a suburban elementary school in east Tennessee. Fifteen of the students were male. Post-test scores from one male student were not included in the statistical analysis because a preliminary screening indicated that he had already mastered the multiplication facts tested in this study. The classroom population represented several ethnic, geographic, and academic backgrounds. Students' participation in the study required parental permission.

Experimental Design

The researcher used the quasi-experimental post-test only control group design.

Grouping	Treatment	Measurement
Experimental Group	Multiplication fact instruction with mnemonic devices	Post-test
Control Group		Post-test

FIGURE 1

Explanation of Experimental Design

Experimental Groups

The researcher assigned all subjects to either the control group or the experimental group. Twelve students belonged to the control group, and eleven students comprised the experimental group. Eleven students, whose scores were included in the statistical analysis, were in each group. In an effort to promote balanced ability between the initial levels of the control and experimental groups, the researcher assigned students to groups based on results from an informal multiplication fact screening conducted prior to the beginning of the study. After ranking the screening scores from highest to lowest, the researcher assigned the student with every other score to the experimental group. In order to avoid bias in assigning the child with the highest screening score to a particular group, the researcher used a table of random numbers. Because the ones digit of the number was odd, the child with the highest score was assigned to the control group. The rest of the students were assigned to groups based on the assignment of the student with the highest score.

Timeline

This study took place during twelve days in a three-week period, before multiplication was reintroduced in the fourth-grade mathematics curriculum. Multiplication instruction was provided only four days per week because the researcher was present at the school only on these days.

Procedure

The researcher worked with the control group for a ten-minute session and with the experimental group for a ten-minute session. The order of the sessions alternated. Both sessions reviewed the multiplication facts in the same order so that both groups spent time on the same facts. This study neither provided mnemonic devices for, nor reviewed, multiplication facts with the operands zero, one, or two. The researcher conducted each group session as follows:

<u>Control Group</u>

1. The researcher removed the control group from the presence of the experimental group. Sessions took place in a hallway separate from the experimental group.

2. The researcher wrote a single-digit multiplication problem on a dry erase board. She read the problem and instructed students to write the problem and the answer on their own dry erase boards.

3. The researcher used a stopwatch to time ten seconds. At the end of ten seconds, the researcher requested that students hold up the dry erase boards, showing their answers.

4. The researcher recited the problem and the answer aloud.

5. Students verbally recited the problem and the answer.

<u>Experimental Group</u>

1. The researcher removed the experimental group from the presence of the control group. Sessions took place in a hallway separate from the control group.

2. The researcher wrote a single-digit multiplication problem on a dry erase board. She read the problem and instructed students to write the problem and the answer on their own dry erase boards.

3. The researcher used a stopwatch to time ten seconds. At the end of ten seconds, the researcher requested that subjects hold up the dry erase boards, showing their answers.

4. The researcher told the students a mnemonic device by which they could remember the answer to the problem.

5. Students verbally recited the problem and the answer.

Post-test

At the end of the three-week period, students in both groups took a timed test on multiplication facts. The test consisted of the forty-nine problems reviewed in the group sessions. Each of the tie problems appeared one time while problems with two different operands as digits appeared twice, with the operands reversed each time. Students had 245 seconds to complete the test (49 problems X 5 seconds per problem). The time per problem figure was based on Campbell and Graham's results, which indicated a mean reaction time of 3.63 seconds for fourth grade students responding orally to multiplication problems. The researcher added approximately one second onto this reaction time in order to compensate for the time required for writing down an answer. In order to avoid any ceiling effects that may have occurred, each subject was given two sets of the facts to complete if time permitted. The second set contained the same facts as the first set, but in a different order. The researcher instructed the subjects to complete the entire first set before moving to the second set.

The researcher constructed the test by writing each of the reviewed problems in order by the first multiplicand. She assigned each problem a number and used a table of random numbers to determine the order in which the problems appeared on the test. Problems were randomly sorted with the stipulation that a problem and its equivalent (e.g. 3 X 4 and 4 X 3) did not appear in successive order.

Statistical Analysis

Test results were reported in terms of a raw score based on the number of correct products achieved in the 245 second time period. The researcher ran an independent samples t-test on the raw data to determine the level of significance that existed in comparing the mean scores between the control and experimental groups.

Chapter 4

RESULTS

The researcher used each student's raw score from a timed test of multiplication facts to run a statistical analysis of the data. An independent samples t-test compared the scores of students who received no mnemonic practice with multiplication facts and students who did practice multiplication facts with mnemonic devices. The mean scores from both groups differed by less than three points. The researcher retains the hypothesis that, at the .05 level of significance, students who receive instruction with mnemonic devices show no significant difference in overall mean scores compared to the mean scores of students who receive no instruction in mnemonic devices. (See Table 1).

TABLE 1

COMPARISON OF MEANS OF CONTROL AND EXPERIMENTAL GROUPS

Groups	N	Mean	Mean Difference	St. Error of Means	T ratio	Sig. 2-tailed*
Control	11	27.4545	-2.2727	6.51356	-.349	.731*
Experimental	11	29.7273				

*Not Significant

Chapter 5

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

Summary of Research

Memorization of the basic multiplication facts comprises a foundational component of elementary school mathematics. Research indicates that the ability to quickly retrieve multiplication products from memory relates to a student's ability to solve more complex problems. While the importance of memorizing multiplication facts is well-substantiated, researchers debate the effectiveness of differing methods of teaching multiplication facts. This study examined the impact that instruction with mnemonic devices had on students' recall of multiplication facts.

Twenty-three fourth grade students from a public elementary school in east Tennessee participated in this study. Based on results obtained from an informal multiplication fact screening, the researcher divided students into a control group and an experimental group. Each group participated in a directed practice of multiplication facts for ten minutes per day. The study spanned twelve days during a three week period before fourth graders had reviewed multiplication concepts in the mathematics curriculum. Control group members practiced multiplication facts by writing the products on dry erase boards. After ten seconds elapsed, the researcher recited the problem and answer aloud and then asked control group members to repeat the problem and answer. Experimental group members followed same basic procedure. However, instead of the researcher saying the problem and answer aloud, she presented a mnemonic device to help students remember the product. At the end of the practice sessions, the researcher administered a timed test of multiplication facts. An independent samples t-test was used to analyze results of the study. Results were not significant.

Conclusions

The use of mnemonic devices for practicing multiplication facts did not produce significant differences in the mean scores of fourth grade students on a timed multiplication test. The mean score of students in the mnemonic group was more than two points higher than the mean of subjects in the control group. While this study does not indicate that mnemonic devices significantly improve recall of facts, neither does it indicate that such devices are detrimental to students seeking to commit multiplication products to memory. The researcher observed that the group receiving the mnemonic treatment exhibited more enthusiasm for practice of facts than did the control group. These results substantiate that the use of mnemonic devices for multiplication practice provides a means of memorization at least as effective as traditional drill and practice of facts.

Several factors may have influenced the results of this study. The researcher conducted this study with a small number of subjects from one fourth-grade classroom. Full randomization of groups was not achieved. After administering an initial screening test, the researcher assigned students to control and experimental groups. In a study with a large number of subjects and randomized grouping, the results might show significant differences.

Effectiveness of the mnemonic devices used in this study depended, in part, on the subjects' connection of the devices to prior knowledge. If students were unfamiliar with some of the concepts presented in the mnemonic device, the mnemonic may have been ineffective.

Some students were absent for part of the practice sessions. When this occurred, the researcher repeated the session with absent students individually or in small groups. In a make-up session, students reviewed for ten minutes, beginning with the multiplication facts that their group practiced on the day that they were absent. This difference in practice group size could have influenced results.

Because of the slight time differences inherent in reciting a multiplication fact and its product and explaining a mnemonic device for the same fact, the control group practiced more problems than did the experimental group. Though the control group practiced more problems, the group which used mnemonic devices and practiced fewer problems received a higher mean score. These results may suggest that in practicing multiplication facts, quality of the interaction with the fact outweighs quantity in product practice.

It is important to remember that both the informal screening and the post-test assessed the subjects' ability to produce answers to multiplication problems in a contrived testing environment, rather than in a genuine problem-solving context.

Recommendations

While the results of this study did not approach statistical significance, the topic of using mnemonic devices to increase students' mastery of multiplication facts warrants further study. Those wishing to replicate this study might choose as subjects students who have never studied multiplication facts. It would be of use to investigate the influence of mnemonic devices upon initial acquisition and retrieval of multiplication facts. Such a study might also compare the speed of acquisition of multiplication facts between those who practice with mnemonic devices and those who use only traditional drill and practice.

An interesting extension of the study might involve replication using both verbal and visual mnemonic devices. The devices in this study were primarily verbal. A combination of visual and verbal mnemonic devices might produce statistically significant results.

Analysis of the kinds of errors made and/or the types of questions answered correctly on the post-test assessment in this study could produce an interesting post hoc study.

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APPENDICES

APPENDIX A

KNOX COUNTY SCHOOLS
ANDREW JOHNSON BUILDING

Dr. Charles Q. Lindsey, Superintendent

September 14, 2001

Anita Zutaut
JBC Box 1044
Knoxville, TN 37998

Dear Ms. Zutaut:

You are granted permission to contact appropriate building-level administrators concerning the conduct of your proposed research. In the Knox County schools final approval of any research study is contingent upon acceptance by the principal(s) at the site(s) where the study will be conducted. Include a copy of this permission form when seeking approval from the principal(s).

In all research studies names of individuals, groups, or schools may not appear in the text of the study unless *specific* permission has been granted through this office. The principal researcher is required to furnish this office with one copy of the completed research document.

Good luck with your study. Do not hesitate to contact me if you need further assistance or clarification.

Yours truly,

Mike S. Winstead, Ph.D.
Coordinator of Research and Evaluation
Phone: (865) 594-1740
Fax: (865) 594-1709

Project No. 117

P.O. Box 2188 • 912 South Gay Street • Knoxville, Tennessee 37901-2188 • Telephone (865) 594-1800

APPENDIX B

Dear Parents,

I consider it a privilege to serve as an intern in your child's fourth grade classroom. While I serve as a teaching intern, I am also taking classes in order to earn my master's degree in education from Johnson Bible College. As part of the requirements for my degree, I will be conducting a research project in your child's classroom.

My research will involve using memory strategies to increase the students' skill in basic multiplication facts. The study will be conducted over three weeks during which I will use two methods for reviewing multiplication facts with students. I believe that the instruction will be beneficial for your child. Students who participate in this study will in no way be identified by name.

I am requesting permission to anonymously include your child's test results in this project. I appreciate you signing and returning the attached permission form. I look forward to working with your child. If you have any questions concerning this project, please feel free to contact me at the school.

Sincerely,

___________	_____________	____________
Anita Zutaut	Nancy DeNovo	Vicki Andrews

I give permission for my child, ______________________________ to participate in the action research project conducted by Miss Anita Zutaut.

I do NOT give permission for my child, ______________________________ to participate in the action research project conducted by Miss Anita Zutaut.

Signature of
Parent/Guardian____

Date____

APPENDIX C

Mnemonic Devices Used in Study

Multiplication Fact(s)	Mnemonic Device
3 X 3=9	A baseball team has nine players with three strikes and three bases.
3 X 4=12 4 X 3=12	All numbers from 1-4 are present.
3 X 5=15 5 X 3=15	When the minute hand is on the three, it is fifteen minutes after the hour.
3 X 6=18 6 X 3=18	An eighteen-wheeler has three doors and six cows loaded inside the truck.
3 X 7=21 7 X 3=21	Century 21™ sold the house with 3 kitchens and seven swimming pools.
3 X 8=24 8 X 3 =24	If you saw three spiders with eight legs each, you would be afraid all day (twenty-four hours).
3 X 9=27 9 X 3=27	The smallest number (three) minus one is two. Two plus seven is nine.
4 X 4=16	When I was sixteen, I drove a car with four wheels and four doors.
4 X 5=20 5 X 4=20	When the minute hand is on the four, it is twenty minutes after the hour.
4 X 6=24 6 X 4=24	Six hours with four year-olds seems like a whole day (twenty-four hours).
4 X 7=28 7 X 4=28	February has twenty-eight days. These are four weeks of seven days.
4 X 8=32 8 X 4=32	If I ate (8) four salads a day, I would have a thirty-two inch waist.
4 X 9=36 9 X 4=36	The smallest number (four) minus one is three. Three plus six is nine.
5 X 5=25	When the minute hand is on the five, it is twenty-five minutes after the hour.
5 X 6=30 6 X 5=30	When the minute hand is on the six, it is thirty minutes after the hour.
5 X 7=35 7 X 5=35	When the minute hand is on the seven, it is thirty-five minutes after the hour.
5 X 8=40 8 X 5=40	When the minute hand is on the eight, it is forty minutes after the hour.
5 X 9=45 9 X 5=45	When the minute hand is on the nine, it is forty-five minutes after the hour.

Multiplication Facts	Mnemonic Device
6 X 6=36	When two camels (humps shown on the sixes), crossed the desert, they were thirsty sixes (36).
6 X 7=42 7 X 6=42	A tall six or seven year old might be four feet two inches.
6 X 8=48 8 X 6=48	"Six asked eight for a date, six times eight is forty-eight" (http://www.multiplication.com/rhyming.htm)
6 X 9=54 9 X 6=54	The smallest number (six) minus one is five. Five plus four is nine.
7 X 7=49	Tevin Seven and Kevin Seven play football for the forty-niner's
7 X 8=56 8 X 7=56	All numbers are present from 5 to 8.
7 X 9=63 9 X 7=63	The smallest number (seven) minus one is six. Six plus three is nine.
8 X 8=64	Eight year-olds should not play Nintendo 64™ for eight hours a day.
8 X 9=72 9 X 8=72	The smallest number (eight) minus one is seven. Seven plus two is nine.
9 X 9=81	The smallest number (nine) minus one is eight. Eight plus one is nine.

APPENDIX D

Name:__________________

Multiplication Facts
(Form A)

6	3	4	8	4	9
x 4	x 7	x 9	x 5	x 6	x 3
8	3	7	4	6	6
x 3	x 9	x 5	x 4	x 6	x 9
5	4	3	3	9	7
x 8	x 8	x 3	x 8	x 4	x 9
4	7	4	8	6	6
x 5	x 6	x 3	x 4	x 5	x 8
8	9	9	7	6	8
x 7	x 3	x 5	x 7	x 3	x 9
7	3	5	4	5	7
x 4	x 6	x 9	x 7	x 6	x 8

$$\begin{array}{r} 3 \\ \times\ 4 \\ \hline \end{array} \quad \begin{array}{r} 7 \\ \times\ 3 \\ \hline \end{array} \quad \begin{array}{r} 5 \\ \times\ 4 \\ \hline \end{array} \quad \begin{array}{r} 9 \\ \times\ 6 \\ \hline \end{array} \quad \begin{array}{r} 5 \\ \times\ 7 \\ \hline \end{array} \quad \begin{array}{r} 9 \\ \times\ 7 \\ \hline \end{array}$$

$$\begin{array}{r} 9 \\ \times\ 8 \\ \hline \end{array} \quad \begin{array}{r} 5 \\ \times\ 5 \\ \hline \end{array} \quad \begin{array}{r} 6 \\ \times\ 7 \\ \hline \end{array} \quad \begin{array}{r} 8 \\ \times\ 6 \\ \hline \end{array} \quad \begin{array}{r} 5 \\ \times\ 3 \\ \hline \end{array} \quad \begin{array}{r} 5 \\ \times\ 8 \\ \hline \end{array}$$

$$\begin{array}{r} 3 \\ \times\ 5 \\ \hline \end{array}$$

Name:____________________

Multiplication Facts
(Form B)

3	8	6	3	8	3
x 6	x 8	x 9	x 7	x 6	x 9
4	7	9	7	8	7
x 3	x 7	x 3	x 3	x 5	x 5
3	4	7	9	6	5
x 4	x 7	x 6	x 8	x 3	x 9
6	3	9	9	9	9
x 8	x 5	x 9	x 5	x 7	x 4
6	4	4	3	4	5
x 6	x 9	x 8	x 3	x 5	x 3
8	6	8	5	5	3
x 7	x 5	x 3	x 4	x 6	x 8

7	8	6	7	5	4
x 4	x 9	x 7	x 9	x 5	x 6
5	9	7	4	8	5
x 8	x 6	x 8	x 4	x 4	x 7
6					
x 4					

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